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# A review on trends and development of rapid prototyping processes in industry

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**Abstract**
Rapid prototyping (RP), also called solid freedom fabrication (SFF) can be defined as a group of several techniques and processes which are used to develop a scale model of an actual physical part by making use of CAD software's whereas the actual development of a physical part is done by the process of 3D printing. The process of rapid prototyping involves layer by layer fabrication of 3D prototypes and generally finds application in the custom made parts i.e. small series parts. Hence rapid prototyping is often the best manufacturing process available for production of complicated parts which are not easily prepared by the use of conventional manufacturing (forming or casting). This review throws light on the various developments and trends in rapid prototyping processes enabling ease in manufacturing of several complicated parts.

**Keywords:** rapid prototyping (RP), additive manufacturing, 3D printing, materials

## Introduction

Industrial and economic development in the whole world have resulted in increase in competitive pressure amongst the various industries caused by globalization and supply to these markets. Such industries are also subjected to great pressure to produce an article within smallest possible time and cost. This area have resulted in giving boost to the implementation of various RP techniques assisting companies to remain competitive and enabling them to produce complicated products with less time and cost. The most important advantage of using rapid prototyping techniques/processes is development of complicated 3D (three dimensional) prototypes which are not easily developed by using conventional manufacturing processes. Initially, the concept of RP was to use it as a prototype model. But advances in the technology have widened the scope of

Its applications. Now RP as a technology is racing towards other emerging branches of rapid tooling (RT) and rapid manufacturing (RM). Today, there are many different types of rapid prototyping processes employed in industries but most popular RP processes are Stereolitography, Selective laser sintering, Fused deposition modeling, Three-dimensional printing, Laminated object manufacturing, Ballistic particle manufacturing, Solid ground curing and Multi jet modeling. Also, these different techniques are used for treating different materials in industry, for example the process of 3D printing is used for metals and ceramics. Nowadays, the RP processes are used widely used in the fields of biomaterials and also for manufacture of medial equipments apart for industrial use. Hence the use of RP have given boost to the manufacturing industries in almost every field and have caused great reduction in time which was earlier needed for manufacturing a component by the use of conventional processes.

## Literature Review

Various investigations have been done by the researchers reflecting the trends and development of Rapid Prototyping processes in Industry and discussions of their work on rapid prototyping has been recorded as follows.

Carlos A. Costa, Paulo Roberto Linzmaier, *et al.*, [1] studied rapid prototyping material degradation: a study of mechanical properties and it was analyzed that there was a reduction in various properties (tensile strength, young's modulus) of material over the span of time and the experiment was performed on resin veroblue 850.The rapid prototype has different industrial applications such as in automobile and the aerospace sectors.

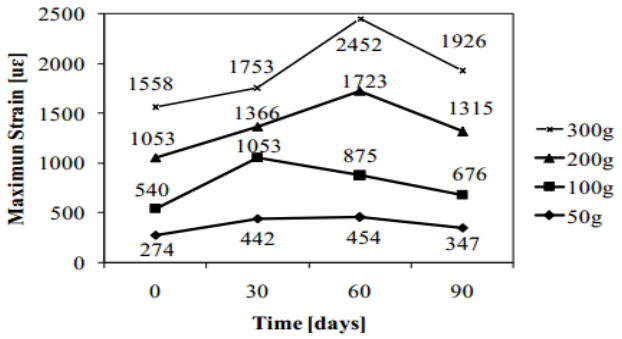


**Fig 1:** Maximum strain versus time showing various loadings.

Wan nurazreena Wan Hassan, Noor azizi mardi, *et al.* [2].studied the comparison of reconstructed rapid prototyping models produced by 3- dimensional printing and conventional stone models with different degrees of crowding. Cuspal tips, fossae and cervical margins are prepared with the help of rapid prototyping. Models produced by rapid prototype posses smooth surfaces and have an advantage over the physical models related to storage and data retrieval. Marlon Wesley Machado Cunico [3] investigated the development of rapid prototyping process. The dimensional accuracy and filaments interaction was studied and it was found that polymerization along the cross section of filament was non uniform. The main objective of rapid prototyping is to increase the functional feasibility of

the system. Caterina Balletti, Francesco Guerra *et al.* [5] examined 3D printing: State of art and future perspectives. The main advantage of 3D technology is it's flexibility. The 3D technology has a vast area of applications which includes analysis, diagnosis, repair, study of the various assests and realization of artificial limbs. Deepen Banoriya, R.K. Dwivedi *et al.* [7] studied the modern trends in rapid prototyping for biomedical applications. The main objective of rapid prototyping is to decrease the development time and costly mistakes and to increase the product lifetime. In biomedical field the rapid prototyping is used in surgery, orthopaedics, tissue engineering and dentistry.

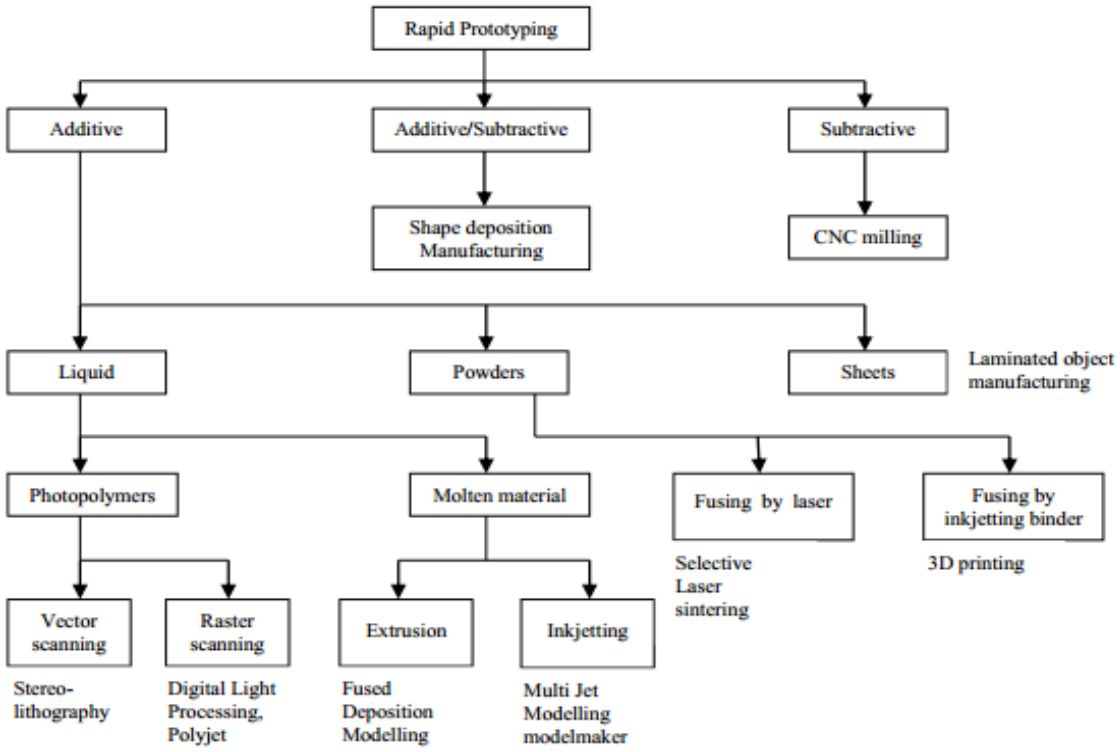


**Fig 2:** Basic classification of RP Processes

Arnaud Bertsch, Philippe Renaud *et al.* [9]. studied rapid prototyping of small size objects and for the manufacturing of the industrial products miniaturization is used. For the rapid prototyping of the small mechanical components the microsteriolithography technique is used and gives the best results. Ian Campbell, Ian Gibnson *et al.* [10]. examined additive manufacturing: rapid prototyping comes of age. The main applications of the additive manufacturing is in the automobile sector, aerospace companies and the medical industries. Speed, accuracy and system cost are the main drawbacks of the additional manufacturing system. Additional manufacturing is used because of the following reasons such as aesthetics, improved functionality and user fit requirements. Chang [12]. studied rapid prototyping. Rapid prototyping also known as solid freeform fabrication is used for the production of the durable objects. Various types of the rapid prototyping systems are used such as Solid based systems, Liquid based system and the powder based system. In manufacturing applications such as casting the rapid prototyping is used.

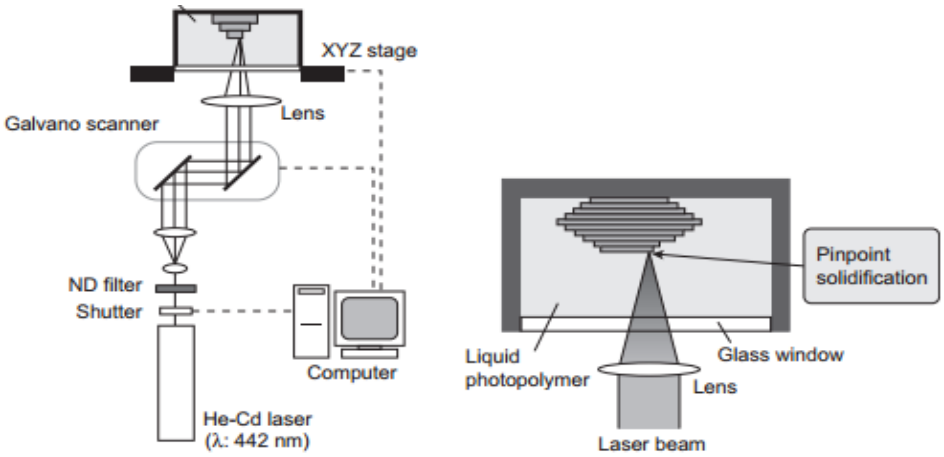


**Fig 3:** (a) Fabrication System (b) Super IH process

**Fig 4:** (a) Original STL (b) prototype with support material (c) prototype without support material

M Gurr, R Mulhaupt [13] studied rapid prototyping and found that the dimensional accuracy, mechanical and the thermal properties of the object were improved. The powder based rapid prototype is the most commonly used because of its easy machine handling and inexpensive equipment. R.L. Hope, R.N. Noth *et al.* [15]. studied rapid prototyping with sloping surface. The sloped surfaces are considered to be more accurate than the stepped edged layers and there is less need for finishing and the building time is reduced.

Pranjal Jaina, A. M. Kuthe [16] studied in Feasibility Study of manufacturing using rapid prototyping: FDM Approach and concluded that RP pattern could be used in sand casting instead of wooden or metallic form as they were troublesome and complicated. RP patterns could be utilized for small quantity as there is no such problem in ramming of sand, cope and drag where there was a chance of failure in conventional patterns. Creating vent holes in the mold in the new process of investment cast was difficult and caused few problems in aeration and venting of gases.

**Fig 5:** CAD model and pattern of investment casting

Kevin K. Jurrens [19] went through Standards for the rapid prototyping industry and found that conclusions regarding the level of participation in RP discussion topic were difficult and discussion in this paper remained unclear. This paper in the virtual conference had exposure of these thoughts to a select spectrum of the RP community and this exposure lead to further analysis of an industry. Anna Kochan [20] in Rapid prototyping trends investigated that use of 3D printing and RP was increasing by each day. In 1996, Stratasys had 34% market in RP and Systems revenues grew by 27% per cent to almost $80 million. According to Wohlers, SPI not being that fast system but with great technology built very small parts, quite accurately with the best surface finish and most impressive detail and they had carved out a niche for themselves.

Jaroslaw Kotlinski [21] studied Mechanical properties of commercial rapidprototyping materials and showed specifications contained all the known mechanical properties of RP materials.

It also differentiated the material properties used in RP methods as the same was found to be useful in designing the mechanical parts and thus was hard to tell which material had dominant property. At present, the work is still going on so therefore, the specifications should not be treated as the associated studies were completed but the studies have brought up increase in accuracy in the manufacturing of the model manufacturing and decrease in surface roughness was seen. S. Kumar, J.-P. Kruth [25] in their work on Composites by rapid prototyping technology reflected that for mechanical applications, the Composites have been fabricated by using RP techniques mainly while its utility for other inter-disciplinaryapplications and SL, LOM had good potentials for the fabrication of continuous fibre-reinforced composites. In enhancing the mechanical applications, there was need to either develop conventional techniques of RPby increment of UC/SLM machines capacity or by creating new RP technique like based on plasma welding. Special powders and SLS/LENS/3DP were the most-easiest way to make composites and the techniques were required to mature for accurate and fast reproducibility. RP had various advantages as compared to traditional techniques in manufacturing of scaffolding items by usage of bio-composite.

Jian-Yuan Lee, JiaAn, Chee Kai Chua [27] gone through Fundamentals and applications of 3D printing for novel materials and reviewed that biocompatible materials were still limited and further development on these materials were still required but 3D printing was versatile in terms of materials. For the novel materials, the new printers and processes has not been investigated beyond seven categories. An integral part of a multi-process system to match the development of novel materials and new requirements of products was likely to be seen in future. Hybrid AM process could also achieve bigger build volume, and multi-material within the same layer for better surface finish. The use of AMin Direct Digital Manufacturing (DDM) resulted in manufacturing of products in low volumes and produced partsthat were to be used as an end product and to or unique products using AM.

S.O. Onuh [30] evaluated Rapid prototyping integrated systems and concluded that Competitive cost with quality and time, able to produce services and product in arbitrary lot, profitable margin, flexible and adaptable towards customers requirement, being human oriented, sharing, interactive and environmentally aware were the set of key required for RP. Such a system shall be acceptable to both industry as well as

to research activities if such key requirements are fulfilled. Daniel B. Short, Daniel Volk, Paul D. Badger, Jason Melzer, Phil Salerno and Arif Sirinterlikci [31] worked on 3D Printing (Rapid Prototyping) photopolymers: An Emerging Source of Antimony to the Environment and reflected that plastic containing 3000 – 8000 mg/Kg sb. model contains 100 times the level of antimony in PETE, this antimony could be released into workplace during sanding and grinding. For cleaning purpose, the use of Isopropyl alcohol and tri - propylene glycol monomethyl ether (TPM) took place. The TPM / resin mixture was treated as hazardous waste as thecleaning solution used becomescontaminated with resin up to around15%. Daniel B Short, Arif Sirinterlikci, Paul Badger, B Artieri[32] in their experiment of Environmental, Health, and Safety Issues in Rapid Prototyping found powder as the material is used for making Powder-based rapid prototyping systems that are primarily used for building the prototyped parts. Nylon or polycarbonate powders were used by the SLS modelers, but metals with plastic, ABS, PVC, were in use as they showed good improvement in the technology and they also decreased the health risk factor.

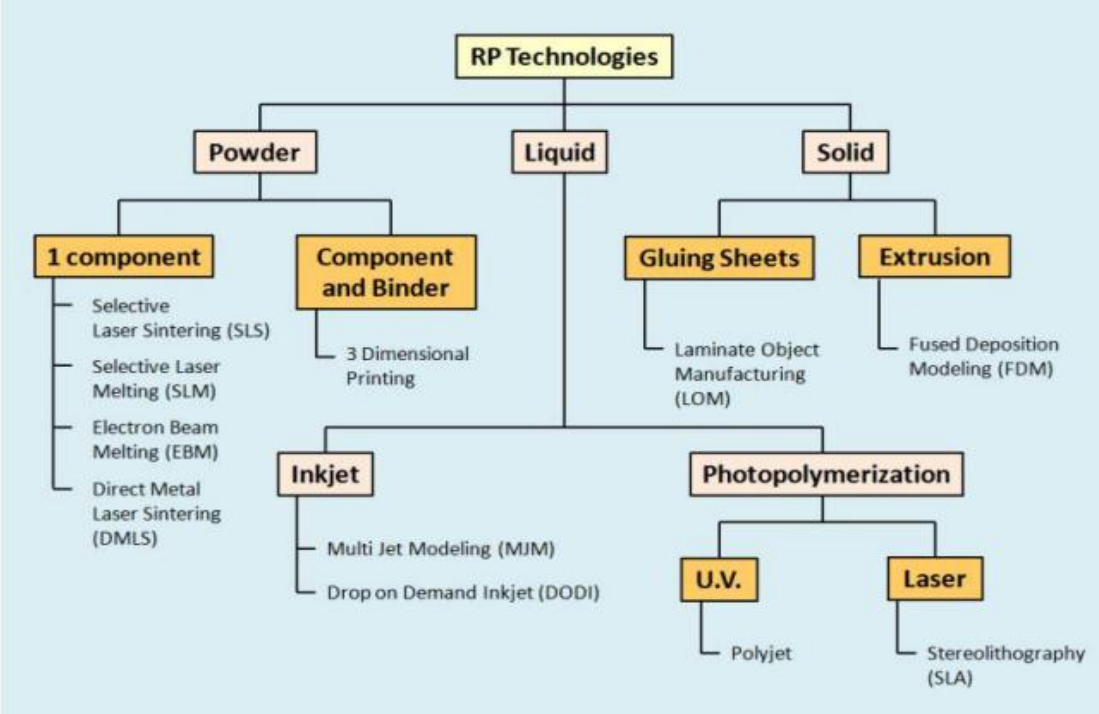


**Fig 6:** Basic Techniques used in RP

Preston G. Smith [33] in his work on the business of rapid Prototyping resulted that when development process is associated with rapid prototyping tools, it reduces schedules and shortens the mechanism in development projects. Various cost saving is done by using RP, and less man-handling makes the products accurate. As the cost decreases, the production rate increases and the cost of the product becomes economical and gives the manufacturing unit profitable margin.

Swift [34] studied the rapid prototyping processes and found that RP could be used in various applications in form and fit parts in assemblies, colored, architectural models, product concept models,Medical models,Casting patterns, Snap fits and hinges Models for ergonomic testing, Surgical planning models.

## Conclusion

Rapid prototyping (RP) technology has the potential to not only reduce the turnaround time in product development, but also to bring significant impact to various areas such as functional prototyping and small production, personal 3D printing, and advancement in medical applications. In biomedical, not only tissue engineering but also the developments of implantable and other prostheses are important applications of RP technology. Also recent developments in the fields of materials sciences, nano-particles and composites have given a boost to the progress of RP techniques resulting in developments of high quality products. Also in some cases RP techniques are also combined with conventional manufacturing processes to take advantage to both, but despite of scientific progress in this field the appropriate choice of an RP process for a given application is still dependent on precise knowledge of individual strengths and weaknesses of the various technologies offered in the market causing a gap between users and technology.

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